Role of aerosol forcing for multi-decadal Atlantic variability in a model ensemble sampling aerosol forcing uncertainty

Andrea Dittus, Ed Hawkins, Laura Wilcox, Rowan Sutton, Jon Robson, Dan Hodson

National Centre for Atmospheric Science, University of Reading, Reading RG6 6BB, UK
contact: a.j.dittus@reading.ac.uk

Introduction

Aerosols are an important climate forcer, as they alter the surface energy budget by scattering and absorbing solar radiation, and altering cloud properties. However, uncertainty in historical aerosol forcing and its climate impacts are large (–1.9 to –0.1 W/m^2 in IPCC AR5). The **SMURPHS** ensemble (Securing Multidisciplinary UndeRstanding and Prediction of Hiatus and Surge events) has been designed to sample this uncertainty in aerosol radiative forcing in a state-of-the-art climate model (Dittus et al., 2020: Sensitivity of historical climate simulations to uncertain aerosol forcing, *Geophys. Res. Lett.,* in press).

Experiment design

Intermediate size ensemble (25 members, 1850-2014) of simulations with HadGEM3-GC3.1 (135km atm., 1 deg. ocean), specifically designed to sample a wide range in historical aerosol forcing.

- Historical CMIP6 forcing
- All anthropogenic aerosol emissions have been scaled by constant scaling factors 0.2, 0.4, 0.7, 1.0 and 1.5, corresponding to a present-day forcing of **-0.38 W/m^2, -0.60 W/m^2, -0.93 W/m^2, -1.17 W/m^2 and -1.50 W/m^2** respectively
- 5 members are run per scaling to sample internal variability

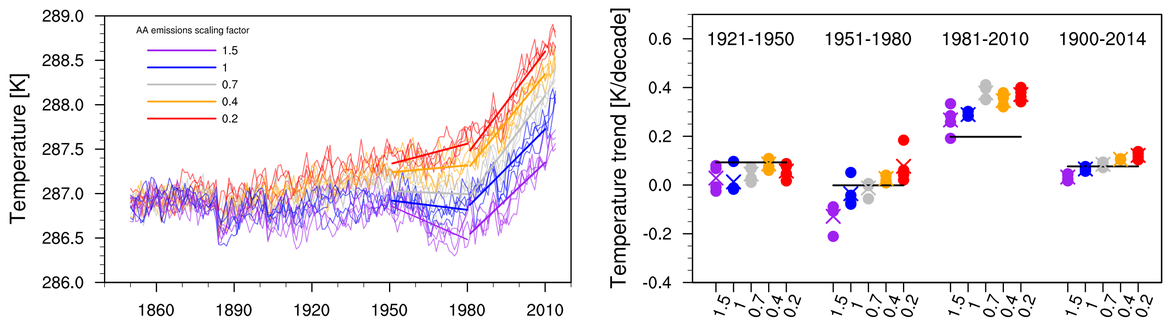

Figure 1: a) Global mean surface temperature in the SMURPHS ensemble b) GMST temperature trends in various periods compared to observations (horizontal black line)

Patterns of global temperature change

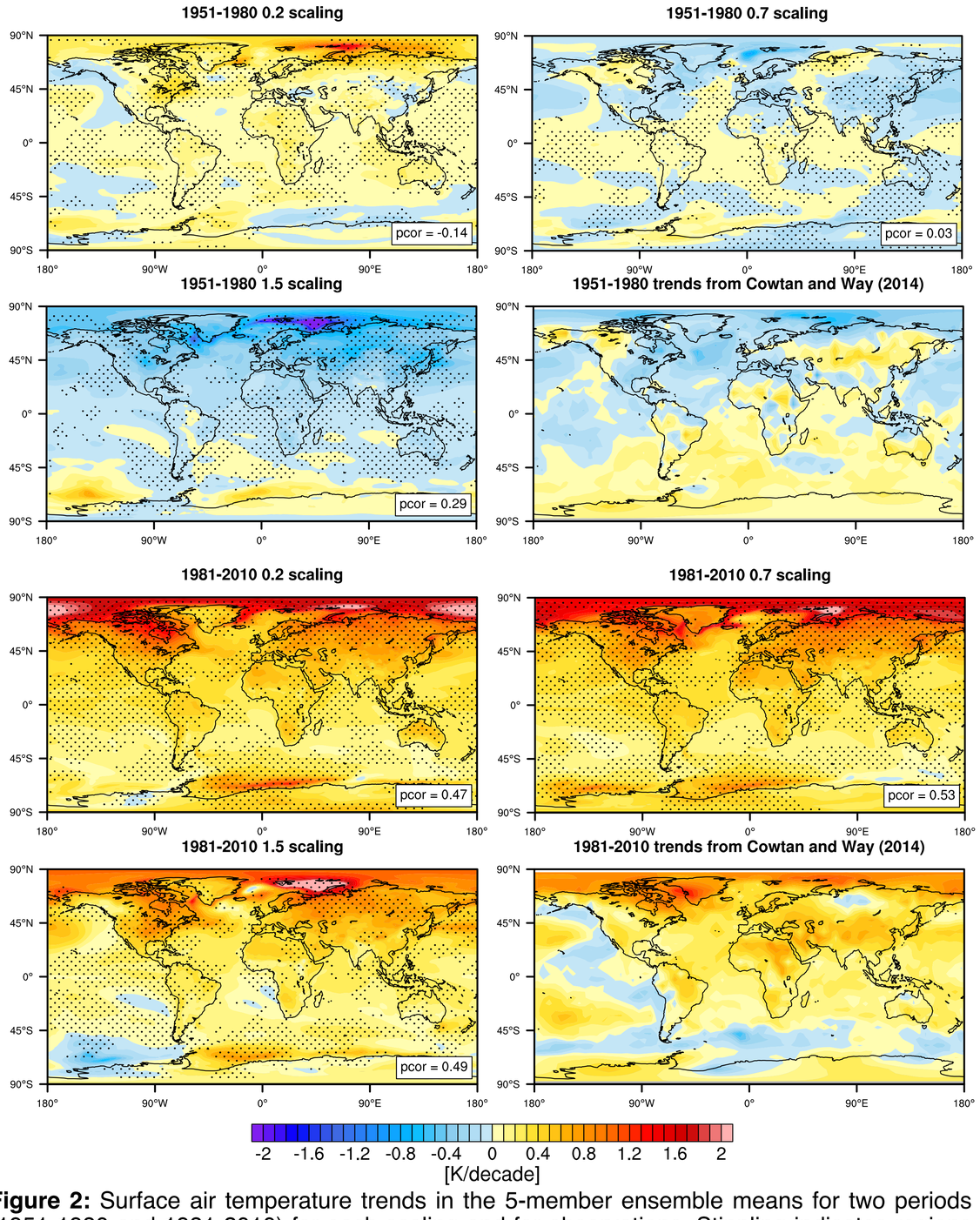

Figure 2: Surface air temperature trends in the 5-member ensemble means for two periods (1951-1980 and 1981-2010) for each scaling and for observations. Stippling indicates regions where the observations lie outside the modelled range.

Atlantic variability

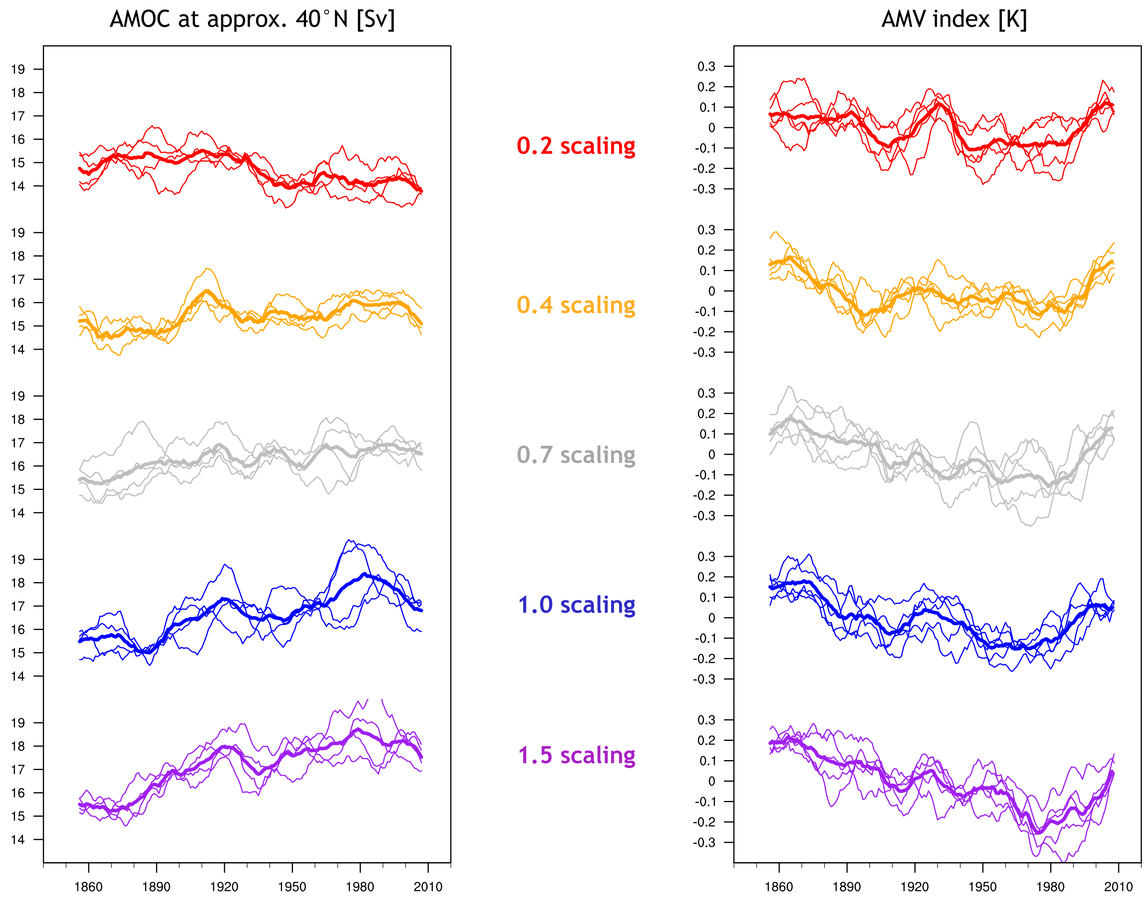

Figure 3: Time series of the Atlantic Meridional Overturning Circulation at approximately 40°N (left) and the Atlantic Multi-decadal Variability (AMV) index (right). A 13-year running mean has been applied to both. AMV is defined as the North Atlantic mean SSTs, with the global mean excluding the Atlantic removed via regression following Sutton and Dong, 2012, *Nature Geosci.*

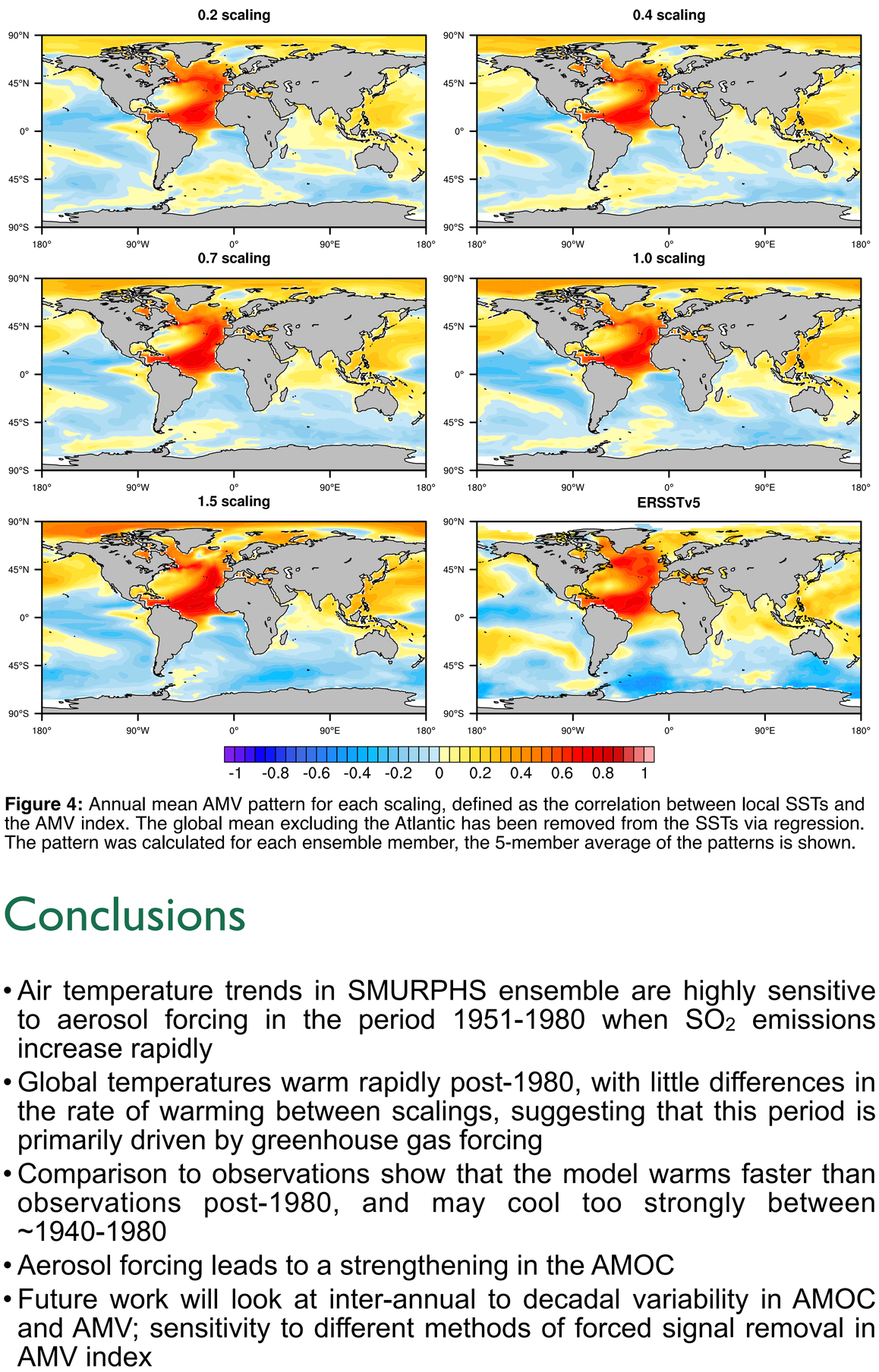

Figure 4: Annual mean AMV pattern for each scaling, defined as the correlation between local SSTs and the AMV index. The global mean excluding the Atlantic has been removed from the SSTs via regression. The pattern was calculated for each ensemble member, the 5-member average of the patterns is shown.

Conclusions

- Air temperature trends in SMURPHS ensemble are highly sensitive to aerosol forcing in the period 1951-1980 when SO_2 emissions increase rapidly
- Global temperatures warm rapidly post-1980, with little differences in the rate of warming between scalings, suggesting that this period is primarily driven by greenhouse gas forcing
- Comparison to observations show that the model warms faster than observations post-1980, and may cool too strongly between ~1940-1980
- Aerosol forcing leads to a strengthening in the AMOC
- Future work will look at inter-annual to decadal variability in AMOC and AMV; sensitivity to different methods of forced signal removal in AMV index

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC SCIENCE OF THE ENVIRONMENT

University of Reading

SMURPHS